



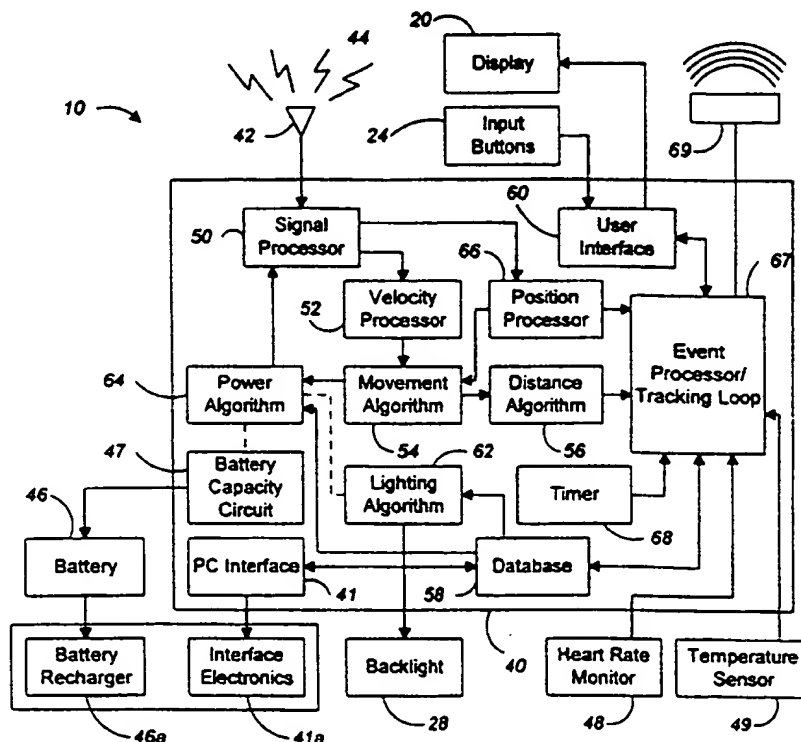
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## (54) Title: DISTANCE TRACKING DEVICE USING GLOBAL POSITIONING SYSTEM SIGNALS

## (57) Abstract

A multifunction wristwear device includes a distance tracking device to calculate the total distance traveled by the wearer during an event by using GPS signals. The distance tracking device automatically adjusts the sampling rate to compensate for blockage of GPS satellites and changes in direction so as to provide the optimal accuracy given the available battery power. The device can provide useful information to the wearer during and after the event through a menu-driven interface on a matrix-type display screen.



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DISTANCE TRACKING DEVICE USING  
GLOBAL POSITIONING SYSTEM SIGNALS

Background

5           The present invention relates generally to personal electronic equipment, and more specifically to distance tracking devices that receive signals from a global positioning system.

          Global positioning system (GPS) receivers for personal use have decreased dramatically in size and price due to developments in semiconductor fabrication  
10   technology and economies of scale. Hand-held devices incorporating GPS receivers are now available for determining the user's absolute position, i.e., the user's latitude and longitude. Such devices are large and heavy, and are typically used for navigational purposes, e.g., to locate the user's position on a map. They may also provide the instantaneous velocity, i.e., the speed and direction, of the user.

15           Although professional and non-professional athletes and other people involved in outdoor activities use a variety of personal electronic equipment in training and during athletic events, such equipment has not taken advantage of GPS technology. While handheld GPS devices have been used by hikers and sportsmen (e.g., fishermen, boaters and small plane owners), these heavy handheld devices are  
20   not practical for many sports (e.g., running, walking, skiing, and in-line skating). In addition, even conventional equipment may have a cumbersome user interface and may be inconvenient to use during an athletic event. For example, a wrist watch which includes a timer and a heart rate monitor may require the wearer to depress a button to view the desired information. This may be difficult, if not impossible, if the  
25   wearer is engaged in strenuous activity.

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Summary

In one aspect, the invention is directed to a distance tracking device. The device has an antenna for receiving a first plurality of GPS signals at a first time and a  
5 second plurality of GPS signals at a second time, a signal processor connected to the antenna to convert the first and second pluralities of GPS signals into GPS data, a timer to measure a time difference between the first time and the second time, a digital processor connected to the signal processor and the timer, and a display to indicate the total distance traveled. The digital processor is configured to determine an  
10 instantaneous velocity from the GPS data, to determine an incremental distance by multiplying the time difference by the instantaneous velocity, and to determine the total distance traveled by summing a series of incremental distances.

Implementations of the invention may include the following. The distance tracking device may be embodied in a wrist wear device having a casing and a wrist  
15 strap, with the display on a face of the casing, and the signal processor, the timer and the digital processor located in the casing. The digital processor may be configured to begin measuring the total distance upon receiving a user input from a button on the casing. The signal processor may be automatically activated at a sampling rate, e.g., faster than about once per five seconds, set by the digital processor. The digital  
20 processor may store a current direction vector and determine the incremental distance from the dot product of the instantaneous velocity and the current direction vector.

In another aspect, the invention is directed to a personal tracking device. The device includes a wristwear type casing, an antenna for receiving a plurality of GPS signals, a signal processor located in the casing, a digital processor located in the  
25 casing and connected to the signal processor, and a display on a face of the casing to display the tracking information. The signal processor is activated periodically and automatically at a sampling rate to convert the plurality of GPS signals into GPS data, and the digital processor is configured to determine tracking information from the GPS data.

30 Implementations of the invention may include the following. The tracking

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information may include a direction of motion and/or a speed, and the digital processor may be configured to adjust the sampling rate in response the direction of motion and/or speed, e.g., by increasing the sampling rate if the direction of motion  
5 changes or the speed changes.

In another aspect, the invention is directed to a tracking device having an antenna to receive a plurality of GPS signals, a signal processor activated periodically and automatically at a sampling rate to convert the plurality of GPS signals into GPS data, and a digital processor connected to the signal processor. The digital processor  
10 is configured to determine a direction of motion from the GPS data and to adjust the sampling rate in response to the direction of motion.

Implementations of the invention may include the following. The sampling rate may be increased if the direction of motion is changing, and decreased if the direction of motion is substantially steady. The digital processor may store a  
15 current direction vector and determine whether the direction of motion is changing by comparing the direction of motion to the current direction vector. A new direction vector may be determined from a series of measurements of the direction of motion after the digital processor determines that the direction of motion differs substantially from the current direction vector.

20 In another aspect, the invention is directed to a tracking device having an antenna to receive GPS signals, a signal processor activated periodically and automatically at a sampling rate to convert the GPS signals into GPS data, a digital processor connected to the signal processor, and a battery. The digital processor is configured to determine tracking information from the GPS  
25 data, to measure a current capacity of the battery, to store an anticipated activity duration, and to determine the sampling rate so as to provide an optimal accuracy over the anticipated activity duration given the current capacity of the battery.

Implementations of the invention may include the following. The digital processor may be configured to periodically measure a remaining capacity of the  
30 battery, to determine a remaining activity duration, and to determine a new sampling

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rate so to provide an optimal accuracy over the remaining activity duration given the remaining capacity of the battery. A user may select between a first mode in which the sampling rate cannot be reduced below a preselected sampling rate, and a second  
5 mode in which the sampling rate can be reduced below the preselected sampling rate. The digital processor may be configured to measure a power consumption rate, and to determine a new sampling rate so to provide an optimal accuracy over the anticipated activity duration given the capacity of the battery and the power consumption rate. The tracking device may include a clock and a light which is activated during times of  
10 darkness indicated by the clock, and the digital processor may be configured to subtract the power required by the light from the available battery capacity when determining the sampling rate. The digital processor may be configured to measure a signal strength of the GPS signals, and to increase the sampling rate if the GPS signals are intermittently blocked or have a low signal strength. The digital processor may be  
15 configured to stop tracking a GPS satellite if its GPS signals are intermittently blocked or have a low signal strength.

In another aspect, the invention is directed to a wristwear device having a wrist watch type casing, a liquid crystal display on a face of the casing, a back light located in the casing behind the liquid crystal display, a clock, and a digital processor  
20 located in the casing and connected to the clock. The digital processor is configured to activate the back light during times of darkness indicated by the clock.

Implementations of the invention may include the following. The digital processor may be configured to operate in a first mode in which a button is depressed to activate the back light and a second mode in which the back light is activated  
25 automatically during times of darkness. The device may include a battery to power the back light and the liquid crystal display.

In another aspect, the invention is directed to a wristwear device having a wrist watch type casing, a matrix-type display screen on a face on the casing, and a digital processor located in the casing and connected to the display screen. The digital  
30 processor is configured to generate a user interface to display information on the

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display screen.

Implementations of the invention may include the following. The display screen may be a liquid crystal display. The digital processor may be configured to  
5 generate a menu-driven user interface on the display screen. A plurality of buttons may be placed on the casing, and the digital processor may be configured to accept user input from the buttons to select an option from a menu. A first button may scroll through options in the menu and a second button may select an option.

Advantages of the invention may include the following. The distance  
10 tracking device incorporates a GPS receiver that is entirely disposed in a wristwear device. The device tracks the total distance traveled by the wearer during an event, and displays this total automatically without user intervention. The GPS sampling rate is selected to provide the optimal accuracy given the available battery power, the expected duration of the event, the terrain and the route of the user. Information about  
15 the wearer's performance may be stored and combined with information from a heart rate monitoring device to provide a complete athletic diagnostic of the event. In addition, information about the event course, such as the number of turns or whether the surroundings block signals from the GPS satellites, may be stored.

Other advantages and features of the present invention will become  
20 apparent from the following description, including the drawings and claims.

#### Brief Description of the Drawings

FIG. 1 is a perspective view of a wristwear device incorporating a GPS receiver.

FIG. 2 is a schematic diagram of a menu displayed on the LCD screen of  
25 the wristwatch of FIG. 1.

FIG. 3 is a block diagram of distance tracking device according to the present invention.

FIG. 4 is a schematic diagram illustrating the movement algorithm of FIG.

3.

FIG. 5 is a block diagram of the database of FIG. 3.

FIG. 6 is a flow diagram illustrating the process performed by the power  
5 management algorithm of FIG. 3.

### Detailed Description

In brief, a distance tracking device according to the present invention uses GPS signals to provide an accurate measurement of the distance traveled by the wearer. The distance tracking device is particularly suited for athletic activities  
10 involving long-distance travel, such as running, hiking, biking, skiing, rowing, walking and in-line skating. Preferably, the distance tracking device is operable in both a "watch" mode for regular use, and an "event" mode for use in training exercises or during athletic events (both hereinafter collectively referred to as "events"). In the event mode, the distance tracking device automatically computes  
15 and displays the distance traveled by the wearer since the beginning of the event. On the other hand, in the watch mode the device acts like a normal wristwatch. The distance tracking device can also display other information, such as the wearer's velocity and heart rate.

Referring to FIG. 1, a distance tracking device 10 is configured as a  
20 wristwear device 12 similar to a wrist watch. The wristwear device 12 includes a wrist watch type casing 14 and a wrist strap 16. A liquid crystal display (LCD) screen 20 is located on a front face 22 of the casing 14. The LCD screen 20 is a matrix-type display, e.g., a miniature computer screen, rather than an LCD having a predetermined pattern for use as a timepiece. The LCD screen 20 may have an array size of about 40  
25 x 80 pixels and a resolution of about 250 pixels per inch. The LCD screen 20 is a monochrome device, although a color LCD screen may be possible if the cost thereof decreases. The LCD screen 20 may be positioned on the face of a swivel display so that the wearer can mechanically pivot the LCD screen to select a preferred viewing angle. A processor located in the casing generates a user interface to display



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information on the LCD screen 20.

A back light 28 is positioned in the casing 14 behind the LCD screen 20 to illuminate the LCD screen 20 in low-light environments. In addition, a battery, a GPS receiver, a microprocessor and a memory are positioned in the casing 14, generally  
5 beneath the LCD screen 20, to perform the distance tracking functions that will be described in detail below.

Two or three buttons 24 project from the front or sides of the casing 14. For example, one large button may be located on the front face of the casing for easy  
10 access during an event, and two buttons may be located on the sides of the casing. The distance tracking device 10 uses a menu-driven interface in which the buttons 24 are used by the wearer to select options from a text or icon-based menu which is generated by the processor. Two of the buttons may be used to scroll up and down through the options in the menu, and one of the buttons may be used to select an  
15 option from the menu. For example, referring to FIG. 2, the LCD screen 20 displays a menu 30 that might be used by the wearer to select the information displayed during the event. The menu 30 includes three entries 32 corresponding to the distance traveled, current speed, or heart rate of the wearer. By presenting a list of text options for the wearer to select, the distance tracking device 10 eliminates the need for the  
20 wearer to memorize a complicated set of button functions. In addition, the LCD screen may display indicia 36 showing the current purpose of the buttons.

Referring to FIG. 3, the LCD screen 20, the buttons 24 and the back light 28 are connected to a general purpose digital microprocessor 40 that is located in the casing of the wristwear device. The microprocessor may be of conventional  
25 construction, and includes a memory and a central processor unit (not shown). For example, the microprocessor 40 may be a 10-20 MHZ processor with about 4-12 megabytes of RAM and about 1-8 megabytes of ROM. The microprocessor 40 is connected to an antenna 42 to receive GPS signals 44 from GPS satellites. The antenna 42 may be embedded in the face of the wristwear casing or in the wrist strap  
30 of the wristwear device. The antenna 42 may be a patch antenna about one-inch

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square and about 4-5 mm high and formed of ceramic materials. The antenna 42 may be connected to a very small ground plane, or the ground plane may be eliminated entirely. The microprocessor 40 converts the GPS signals received by the antenna 42 into velocity, speed and location information that is then used to generate an accurate measurement of the distance traveled by the wearer. The microprocessor 40 may also be connected to other sensors, such as a heart rate monitor 48 and a temperature sensor 49. The heart rate monitor 48 and temperature sensor 49 may be of conventional construction.

10 The LCD screen 20, the back light 28 and the microprocessor 40 are powered by a rechargeable battery 46. For example, the battery 46 may be a solid state lithium ion rechargeable battery that provides approximately 650 milliamps of current. The battery 46 may be located in the casing or the wrist strap of the wristwear device. The battery 46 may be distributed in a number of small cells, e.g., 15 two or three cells each producing 150-200 milliamps of current, with lightweight aluminum casings. The battery 46 is connected to a battery recharger 46a of generally conventional construction.

The microprocessor 40 includes or is programmed with several functional components, including a signal processor 50, a velocity processor 52, a movement algorithm 54, a distance algorithm 56, a database 58, a user interface 60, a lighting algorithm 62, a power algorithm 64, a timer 68 and an event processor/tracking loop 67 to coordinate the operation of the functional components. Each of these elements will be described in greater detail below.

The timer 68 provides a local clock and other functions typically associated with a timepiece, such as a stop watch, a count-down timer, and one or more alarms. In the watch mode, the LCD screen 20 displays the local time. However, the wearer may use the menu-driven interface to invoke the other functions of the timer, to review performance data recorded from earlier events, to program the distance tracking device for an upcoming event, or to cause the distance tracking device to enter the event mode.

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The signal processor 50 is connected to the antenna 42 to act as a receiver for the GPS signals 44. The signal processor 50 includes an amplifier to boost the signals from the antenna 42, a down converter to translate the carrier of the GPS signals 44 to a frequency suitable for digital processing, and a code spreader to remove the spreading codes and recover the raw GPS data, including ranging, frequency and timing information, from the GPS signals 44. Although the signal processor 50 is illustrated as part of the microprocessor 40, the signal processor 50 may be implemented as a separate device.

10 The velocity processor 52 receives the raw data from the signal processor 50, and calculates the wearer's current velocity, including the wearer's speed and direction of travel. This calculation may be performed according to conventional techniques. When the distance tracking device is in the event mode, the signal processor 50 is activated periodically and automatically to provide data to the velocity processor 52. The velocity processor 52 then automatically generates a sequence of velocity measurements. The frequency, or sampling rate, with which the signal processor 50 and the velocity processor 52 are activated to convert the GPS signals 44 into velocity measurements will vary. However, the sampling rate is typically between two to three times per second and two to three times per minute. The GPS sampling rate is controlled by the power algorithm 64, as described below in greater detail.

The velocity measurements calculated by the velocity processor 52 are provided to the movement algorithm 54. In brief, the movement algorithm 54 converts the sequence of individual velocity measurements from the velocity processor 52 into a series of straight line segments.

Referring to FIG. 4, the movement algorithm stores a current straight-line vector,  $K_1$ , which represents the current direction of motion of the wearer from an anchor point  $X_1$ . As each new velocity measurement,  $V_1$ , is received from the velocity processor, it is compared to the current straight-line vector  $K_1$ . If the new velocity  $V_1$  is consistent with the current straight-line vector  $K_1$ , i.e., if it is within the expected

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margin of error for GPS signals, then a new position point is created at a point  $X'_1$  which is consistent with the straight-line vector. Specifically, the incremental distance  $\Delta d$  traveled by the wearer may be computed by the function  $\Delta d = \Delta t |V_1| \cos \phi$ , where  $\Delta t$  is the time since the previous velocity measurement,  $V_1$  is the velocity measurement, and  $\phi$  is the angle between the velocity  $V_1$  and the current straight-line vector  $K_1$ . On the other hand, if a new velocity measurement  $V_2$  is considerably different than the current straight line vector  $K_1$ , the movement algorithm indicates a possible change in direction. If additional velocity measurements are consistent with the new direction, then the movement algorithm marks the initial velocity measurement as a new anchor point  $X_2$ . In addition, the movement algorithm computes a new straight-line vector  $K_2$  from the velocity measurements taken following the anchor point  $X_2$ . For example, the six or seven velocity measurements taken after the anchor point  $X_2$  may be averaged to calculate a new straight-line vector  $K_2$ . Finally, the incremental distance measurement  $\Delta d$  is computed from the new straight line vector, i.e.,  $\Delta d = \Delta t |V_2| \cos \phi$ , where  $\phi$  is the angle between the measured velocity  $V_2$  and the new straight-line vector  $K_2$ . Each anchor point and each straight-line vector may be saved in the database to create a schematic map of the event route.

An advantage of this movement algorithm is that it provides an accurate measurement of the distance traveled by the wearer. Athletes, such as runners, walkers, cross-country skiers and in-line skaters tend to move into straight-line segments interrupted by quick changes of direction. Thus, small changes in direction indicated by the velocity processor are likely to be signal noise rather than actual changes in direction. In addition, even if there are small changes in actual direction of motion, the athlete is usually more interested in the distance traveled along the route rather than the total distance traversed. For example, if a runner is inefficient and travels in a zig-zag path along a road, the actual distance traversed by the athlete will be greater than the distance traveled along the route. By reducing the velocity measurements to a set of straight-line segments, both of these sources of error are eliminated.

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Returning to FIG. 3, the incremental distance measurement  $\Delta d$  calculated by the movement algorithm 54 is passed to the distance algorithm 56 to calculate the total distance traveled. The distance algorithm 56 may simply maintain a running  
5 sum of the distance traveled. That is, the distance algorithm calculates the total distance traveled  $D_{total}$  according to the equation  $D_{total} = D_{total} + \Delta d$ .

The current speed,  $|V|$ , and total distance traveled,  $D_{total}$ , as measured by the velocity processor 52 and distance algorithm 56 respectively, are periodically and automatically saved to the database 58 to create an event profile. An entry may be  
10 made in the database 58 at a rate between, for example, once per second and once every two to five minutes, as measured by the timer 68. The frequency with which the entries are added to the database can be set by the wearer using the user interface 60, and may depend on the total available memory in the microprocessor 40. Referring to FIG. 5, each entry 70 may include the elapsed time 72 since the  
15 beginning of the event, the distance traveled 74 since the beginning of the event, the current speed and direction of travel 76 of the user, and additional information such as the temperature, or the user's position or heart rate 78.

The information in database 58 may be used to create a route retrace feature to assist the wearer return to the beginning of the event course (e.g., at the end  
20 of a trail or in an unknown city). For example, the locations where the user changed direction may be displayed and replayed in reverse order so that the wearer can retrace the course.

Returning to FIG. 3, the device may include a personal computer interface 41 to permit the wearer to download the event profile to a personal computer. The  
25 interface 41 may also permit the wearer to customize the information displayed on the LCD screen, to set a user profile (e.g., the type of information to be recorded in the event log, the volume for any audible alarm) or to load information for the automatic lighting and automatic time zone correction features discussed below. The interface electronics 41a for the computer interface 41 may be housed in the battery recharger  
30 46b, and may include a serial connection or an infrared link.

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The user interface 60 receives input from buttons 24 and generates the text or icons to display on the LCD screen 20. The user interface 60 can cause the LCD screen 20 to display information from the velocity processor 52, the distance algorithm 56 or the database 58. Before the event, the wearer may program the distance tracking device by selecting the information that is to be displayed on the LCD screen 20 when the distance tracking device is in the event mode. For example, the user may use the menu 30 (see FIG. 2) to select from elapsed time, total distance traveled, current speed, heart rate. During the event, the user interface 60 displays the selected information automatically and continuously on the LCD screen 20. That is, the wearer does not need to press the buttons 24 to activate the signal processor 50 or the velocity processor 52, or to display the total distance traveled since the beginning of the event. Specifically, the user may cause the LCD screen to display information in a scan mode in which the LCD screen cycles through a series data display screens, displaying each data display screen for about two to five seconds. Following the event, the wearer may review the event profile from the database 58 to evaluate his or her performance.

In order to view the LCD screen 20, the wearer may need to activate the back light 28. The back light 28 is controlled by the lighting algorithm 62. If the wearer will be participating in an outdoor event in low-light conditions, a night-time activity option may be selected from the user interface 60. If the distance tracking device 10 is in the watch mode, the lighting algorithm causes the tracking device to function like a normal wrist watch, i.e., the wearer depresses one of the buttons 24 in order to activate the back light 28. On the other hand, if the distance tracking device 10 is in the event mode and the night-time activity option is selected, then the lighting algorithm 62 determines the time of day from the timer 68 and automatically turns on the back light 28 if it is dusk or night. Specifically, the database 58 may store a lookup-table with times of dawn and dusk as a function of the day of the year and geographic position. The microprocessor 40 can receive the wearer's position from the position processor 66 and the date from the timer 68 and use this information to

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determine the times of dusk and dawn from the lookup table. Thus, if it is dark during all or part of the event, the wearer need not press the buttons 24 during the event to activate the back light 28.

5           As previously noted, the sampling rate of the signal processor 50 is controlled by the power algorithm 64. In brief, the power algorithm 64 sets the sampling rate to provide the optimal accuracy given the available battery power. The power algorithm 64 operates automatically without intervention by the user. The power algorithm 64 increases the sampling rate when the GPS signals 44 are blocked  
10 or obscured, or when the wearer is changing direction. This ensures that accuracy is maintained when the wearer is under dense foliage or surrounded by buildings, or when the wearer makes a turn on a winding path.

Referring to FIG. 6, the power algorithm 64 begins by initializing a set of variables (step 80). These variables include the expected operating time, a route  
15 curvature coefficient, a satellite blockage coefficient and a nighttime viewing coefficient. The expected operating time is the anticipated duration of the event, and it may be entered by the wearer or retrieved from the log of previous events stored in the database. The route curvature coefficient indicates the circuitousness of the event route. An individual moving in a straight line requires fewer samples than a person  
20 moving on a winding path to achieve the same level of accuracy in the measurement of the total distance traveled. The satellite blocking coefficient represents whether the environment will block the GPS signals. More samples need to be taken if the GPS signal strength is low or if the GPS signals are frequently blocked in order to maintain the same level of accuracy. The route curvature coefficient and the satellite blockage  
25 coefficient may either be input by the wearer, or retrieved from the log of previous events in the database. The nighttime viewing coefficient represents the percent of the event that will occur outside in the dark, i.e. the time when the back light will need to be activated. Again, the nighttime viewing coefficient may be set by the wearer, retrieved from the event log in the database, or estimated based on the time and date  
30 of the event.

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Once the coefficients are initialized, the power algorithm measures the capacity of battery 46 using a battery capacity circuit 47. From the battery capacity and the various coefficients, the power algorithm determines the number of satellites to track and a base sampling rate to provide the optimal accuracy for the available battery capacity (step 82). For example, for a circuitous route, the base sampling rate will be decreased. Although fewer samples will be taken during the straight portions of the route, more power will be available to take samples in the winding portions of the route. Thus, the accuracy of the measurement of the distance traveled is not degraded in the winding portions of the route.

If the available battery capacity is low, i.e., insufficient to provide a minimum sampling rate of about 3-5 seconds for the expected duration of the event, the device queries the wearer to determine whether a "fine" mode or a "coarse" mode is preferred. In the fine mode, the minimum base sampling rate is maintained but the GPS tracking powers off early. In the coarse mode, the base sampling rate is reduced below the minimum sampling rate.

Once the initialization step is complete, the distance tracking device waits for the wearer to start the event mode. Once the event mode has begun, the GPS signals are sampled at the preestablished base sampling rate to compute the tracking information, including the wearer's velocity and the distance traveled (step 84). As previously discussed, the distance tracking device can automatically display the total distance traveled on the LCD screen without wearer intervention.

The power algorithm adjusts the sampling rate in reaction to the movement algorithm (step 86). If the movement algorithm senses a change in direction, then the sampling rate is increased, whereas once the movement algorithm senses a new straight-line trajectory, the sampling rate is decreased (see also FIG. 4). If the wearer is traveling a known route, then the movement algorithm may access a log of anchor points for the route as stored in the database 58. The movement algorithm decreases the sampling rate in the straight-line segment between the expected anchor points and increases the sampling rate just before anchor points to sense when the change in



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direction occurs.

The power algorithm 64 also adjusts the sampling rate to compensate for the speed of the wearer (step 88). If the wearer is moving slowly, the sampling rate  
5 may be decreased, whereas if the wearer is moving quickly, the sampling rate may be increased.

In addition, a power algorithm 64 may adjust the sampling rate and the number of satellites tracked in reaction to the strength of the GPS signals (step 90). Every one to two minutes, the power algorithm 64 determines which satellites have  
10 had a consistently low signal strength or have been frequently blocked. The distance tracking device stops tracking the satellites that are frequently blocked or have low signal strength, and scans for and adds new satellites. However, if only a limited number of satellites, e.g., two or three, are available and the signal strength is low, the power algorithm 64 will increase the sampling rate so that the distance tracking device  
15 is more likely to capture a good signal when the satellite is in clear view. On the other hand, if the signal strength returns to a normal level, then the power algorithm decreases the sampling rate.

The power algorithm 64 periodically recomputes the power projection (step 92). Every three to five minutes the power algorithm 64 measures the remaining  
20 battery capacity, the expected remaining operating time, and the current rate of power consumption. The power algorithm then recalculates the sampling rate to provide the optimal accuracy for the remaining battery capacity. Specifically, if the battery capacity circuit 47 detects that the battery is low, the power algorithm may switch to the coarse mode and wearer may be alerted by a flashing icon or an audible alarm.

25 During the event, the changes in the sampling rate caused by changes in direction or low GPS signal strength are recorded to an events statistics log (step 94). If the same course or route is traveled at a later date, the event statistics log may be used in the initialization step 80, as previously discussed, to set the various coefficients.

30 Finally, at the end of the event, the distance tracking device prompts the

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wearer to view data concerning the event in a "summary" mode (step 96). In the summary mode, statistics for the event, such as total distance traveled, average speed, time above or below a target goal, average heart rate, calories burned, are displayed to the wearer. When the wearer has finished viewing the summary data, the device returns to the watch mode (step 98). The event and summary modes may either expire automatically at the end of the expected event duration, or the wearer may use a button to instruct the microprocessor to switch to the summary mode or return to the watch mode.

Returning to FIG. 3, although the distance tracking device 10 is particularly suited for the measurement of distance traveled during an event, the distance tracking device 10 may also be used to determine the wearer's absolute position. The microprocessor 40 may include a position processor 66. The position processor 66 receives raw GPS data from the signal processor 50 and calculates the latitudinal and longitudinal position of the wearer in a conventional manner. The position processor 66 may be activated periodically and automatically, for example, every half hour, by the timer 68 in order to assemble a log of the wearer's position through the day. Such position measurements are useful in events involving all-day travel, such as cross-country skiing, hiking and bicycling.

The processor 40 may also include an automatic time-zone correction feature. The database 58 may store information on the location of the boundaries between time zones. The microprocessor can compare the position measurement generated by the position processor 66 to the stored time zone locations to determine whether the user has changed time zones and update the local clock provided by the timer 68.

The wristwear device 12 also typically includes a speaker 69 to provide an audible alarm for a variety of uses. For example, the processor may be configured to trigger the speaker to provide time markers (e.g., a long beep every 10 minutes and a short beep every 5 minutes), distance markers (e.g., a long beep each mile and a short beep every 1/10 of a mile), heart rate feedback (e.g., a beep if the wearer's heart rate is

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above or below preset thresholds), or speed feedback (e.g., a beep if the wearer's speed rate is above or below preset thresholds).

In summary, the distance tracking device calculates the total distance  
5 traveled by the wearer during an event by using GPS signals. The distance tracking device automatically adjusts the sampling rate to compensate for blockage of GPS satellites and changes in direction so as to provide the optimal accuracy given the available battery power. The device can provide useful information to the wearer during and after the event through a menu-driven interface.

10 What is claimed is:

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1. A distance tracking device, comprising:
  - an antenna for receiving a first plurality of GPS signals at a first time and a second plurality of GPS signals at a second time;
  - 5 a signal processor connected to the antenna to convert the first and second pluralities of GPS signals into GPS data;
  - a timer to measure a time difference between the first time and the second time;
  - a digital processor connected to the signal processor and the timer, the
  - 10 digital processor configured to determine an instantaneous velocity from the GPS data, to determine an incremental distance by multiplying the time difference by the instantaneous velocity, and to determine a total distance traveled by summing a series of incremental distances; and
  - a display to indicate the total distance traveled.
- 15 2. The distance tracking device of claim 1, wherein the distance tracking device is embodied in a wrist wear device having a casing and a wrist strap, and wherein the display is on a face of the casing, and the signal processor, the timer and the digital processor are located in the casing.
3. The distance tracking device of claim 2, wherein the digital processor is
- 20 configured to begin measuring the total distance upon receiving a user input from a button on the casing.
4. The distance tracking device of claim 1, wherein signal processor is automatically activated at a sampling rate set by the digital processor.
5. The distance tracking device of claim 4, wherein the sampling rate is faster
- 25 than about once per five seconds.

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6. The distance tracking device of claim 1, wherein the digital processor stores a current direction vector and determines the incremental distance from the dot product of the instantaneous velocity and the current direction vector.

5 7. A personal tracking device, comprising:

a wristwear type casing;

an antenna for receiving a plurality of GPS signals;

a signal processor located in the casing, the signal processor activated periodically and automatically at a sampling rate to convert the plurality of GPS

10 signals into GPS data;

a digital processor located in the casing and connected to the signal processor, the digital processor configured to determine tracking information from the GPS data; and

a display on a face of the casing to display the tracking information.

15 8. The personal tracking device of claim 7, wherein the tracking information includes a direction of motion.

9. The personal tracking device of claim 8, wherein the digital processor is configured to adjust the sampling rate in response the direction of motion.

10. The personal tracking device of claim 9, wherein the digital processor is  
20 configured to increase the sampling rate if the direction of motion changes.

11. The personal tracking device of claim 7, wherein the tracking information includes a speed.

12. The personal tracking device of claim 11, wherein the digital processor is configured to change the sampling rate if the speed changes.

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13. The personal tracking device of claim 12, wherein the digital processor is configured to increase the sampling rate if the speed increases.

14. A tracking device, comprising:  
5 an antenna to receive a plurality of GPS signals;  
a signal processor activated periodically and automatically at a sampling rate to convert the plurality of GPS signals into GPS data; and  
a digital processor connected to the signal processor, wherein the digital processor is configured to determine a direction of motion from the GPS data and to  
10 adjust the sampling rate in response to the direction of motion.

15. The tracking device of claim 14, wherein the digital processor is configured to increase the sampling rate if the direction of motion is changing.

16. The tracking device of claim 15, wherein the digital processor is configured to decrease the sampling rate if the direction of motion is substantially  
15 steady.

17. The tracking device of claim 14, wherein the digital processor stores a current direction vector and determines whether the direction of motion is changing by comparing the direction of motion to the current direction vector.

18. The tracking device of claim 17, wherein the digital processor is  
20 configured to change the current direction vector to a new direction vector if the direction of motion differs substantially from the current direction vector.

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19. The tracking device of claim 18, wherein the new direction vector is determined from a series of measurements of the direction of motion after the digital processor determines that the direction of motion differs substantially from the current  
5 direction vector.

20. The tracking device of claim 14, wherein the tracking device is embodied in a wrist wear device having a casing and a wrist strap, and wherein the signal processor and the digital processor are located in the casing.

21. A tracking device, comprising:  
10 an antenna to receive GPS signals;  
a signal processor activated periodically and automatically at a sampling rate to convert the GPS signals into GPS data;  
a digital processor connected to the signal processor, the digital processor configured to determine tracking information from the GPS data; and  
15 a battery to power the signal processor and the digital processor, wherein the digital processor is configured to measure a current capacity of the battery, to store an anticipated activity duration, and to determine the sampling rate so as to provide an optimal accuracy over the anticipated activity duration given the current capacity of the battery.

20 22. The tracking device of claim 21, wherein the digital processor is configured to periodically measure a remaining capacity of the battery, determine a remaining activity duration, and determine a new sampling rate so to provide an optimal accuracy over the remaining activity duration given the remaining capacity of the battery.

23. The tracking device of claim 21, wherein a user may select between a first mode in which the sampling rate cannot be reduced below a preselected sampling rate, and a second mode in which the sampling rate can be reduced below the preselected  
5 sampling rate.
24. The tracking device of claim 21, wherein the digital processor is configured to measure a power consumption rate, and to determine a new sampling rate so to provide an optimal accuracy over the anticipated activity duration given the capacity of the battery and the power consumption rate.
- 10 25. The tracking device of claim 21 further comprising a clock and a light which is activated during times of darkness indicated by the clock, and wherein the digital processor is configured to subtract the power required by the light from the available battery capacity when determining the sampling rate.
26. The tracking device of claim 21, wherein the digital processor is  
15 configured to measure a signal strength of the GPS signals, and wherein the digital processor increases the sampling rate if the GPS signals are intermittently blocked or have a low signal strength.
27. The tracking device of claim 26, wherein the antenna receives the GPS signals from a plurality of GPS satellites, the digital processor tracks the plurality of  
20 GPS satellites, and the digital processor is configured to stop tracking one of the GPS satellites if its GPS signals are intermittently blocked or have a low signal strength.
28. The tracking device of claim 21, wherein the tracking device is embodied in a wrist wear device having a casing and a wrist strap, and wherein the signal processor, the digital processor and the battery are located in the casing.



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29. A wristwear device, comprising:  
a wrist watch type casing;  
a liquid crystal display on a face of the casing;  
5 a back light located in the casing behind the liquid crystal display;  
a clock; and  
a digital processor located in the casing and connected to the clock, the  
digital processor configured to activate the back light during times of darkness  
indicated by the clock.
- 10 30. The wristwear device of claim 29, wherein the digital processor is  
configured to operate in a first mode in which a button is depressed to activate the  
back light and a second mode in which the back light is activated automatically during  
times of darkness.
31. The wristwear device of claim 29, further comprising a batter to power the  
15 back light and the liquid crystal display.
32. A wristwear device, comprising:  
a wrist watch type casing;  
a matrix-type display screen on a face on the casing; and  
a digital processor located in the casing and connected to the display  
20 screen, the digital processor configured to generate a user interface to display  
information on the display screen.
33. The wristwear device of claim 32, wherein the display screen is a liquid  
crystal display.
34. The wristwear device of claim 32, wherein the digital processor is  
25 configured to generate a menu-driven user interface on the display screen.

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35. The wristwear device of claim 34, further comprising a plurality of buttons on the casing, and wherein the digital processor is configured to accept user input from the buttons to select an option from a menu.
- 5 36. The wristwear device of claim 35, wherein a first button scrolls through options in the menu and a second button selects the option.

FIG. 1

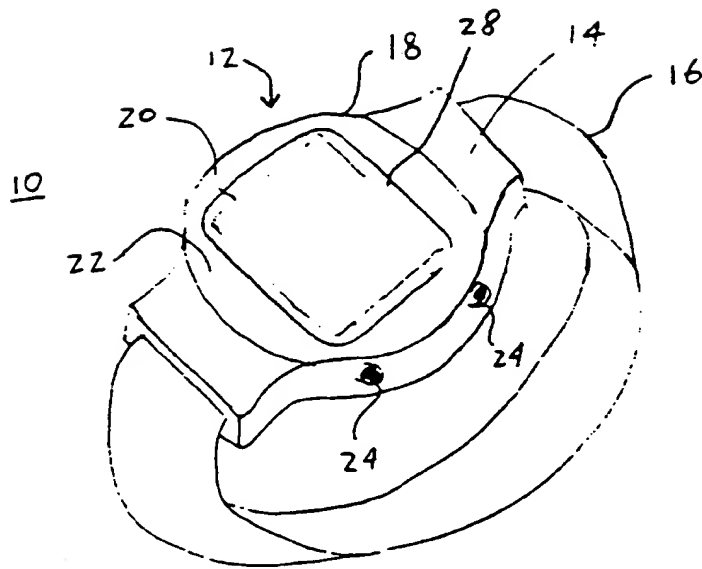


FIG. 3

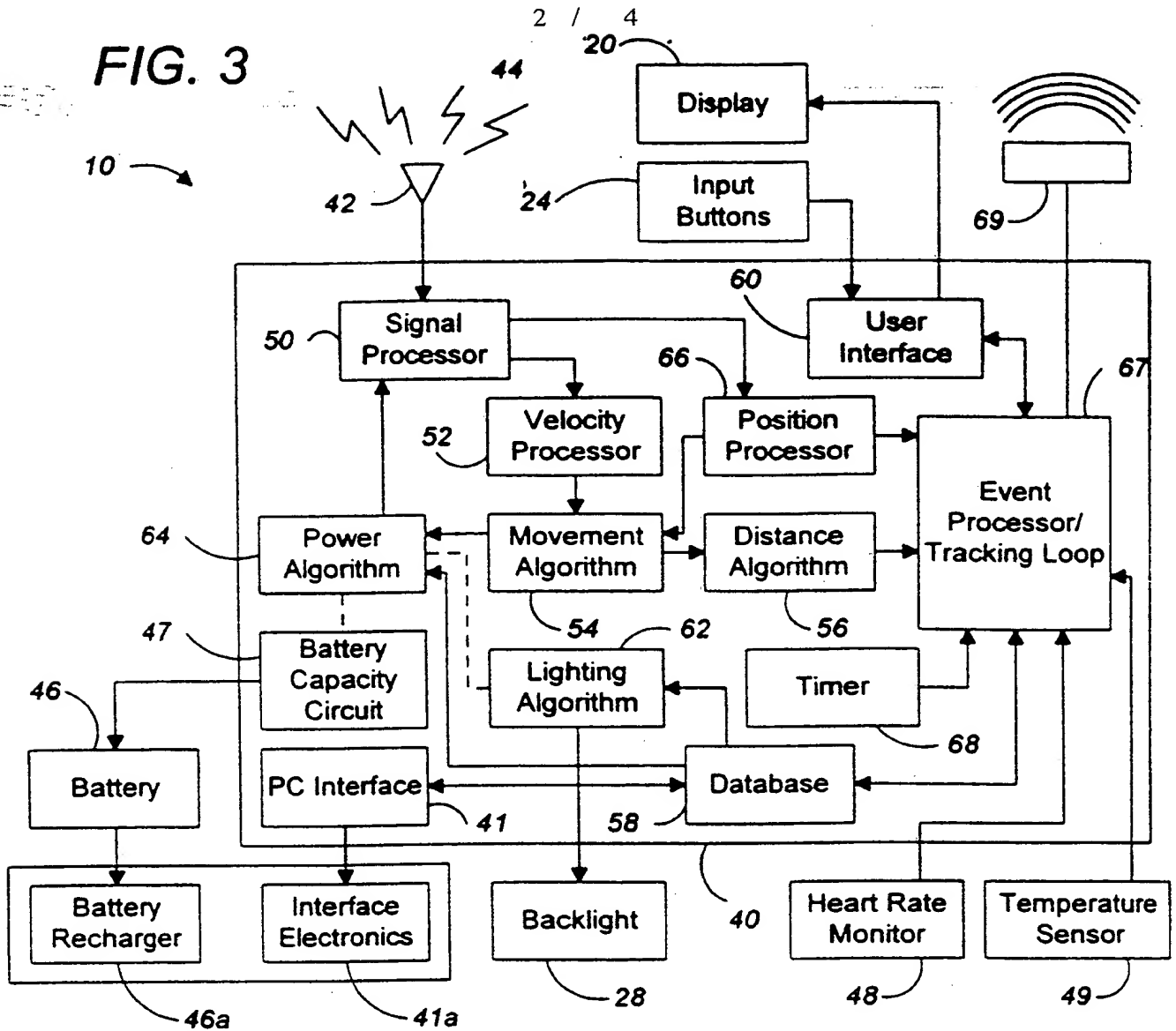
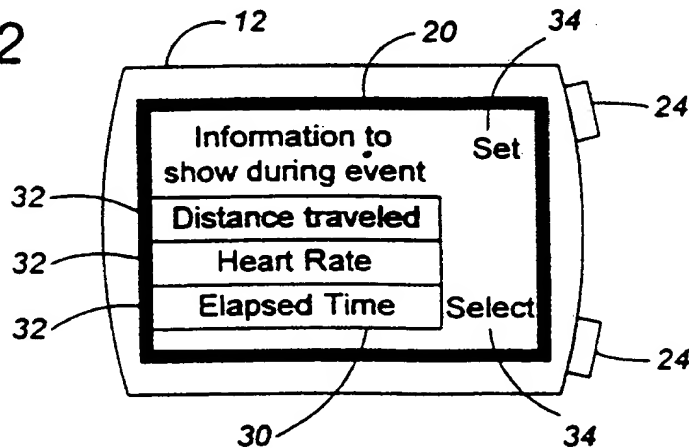


FIG. 2



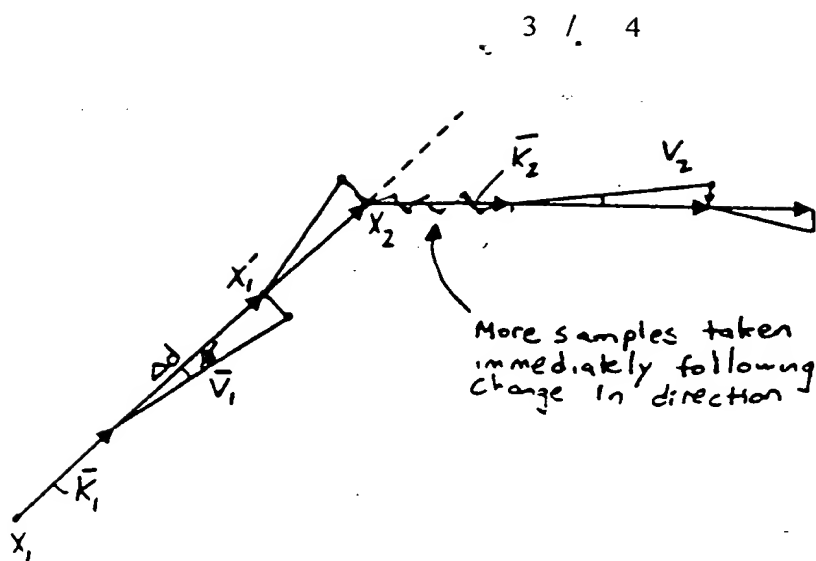


FIG. 4

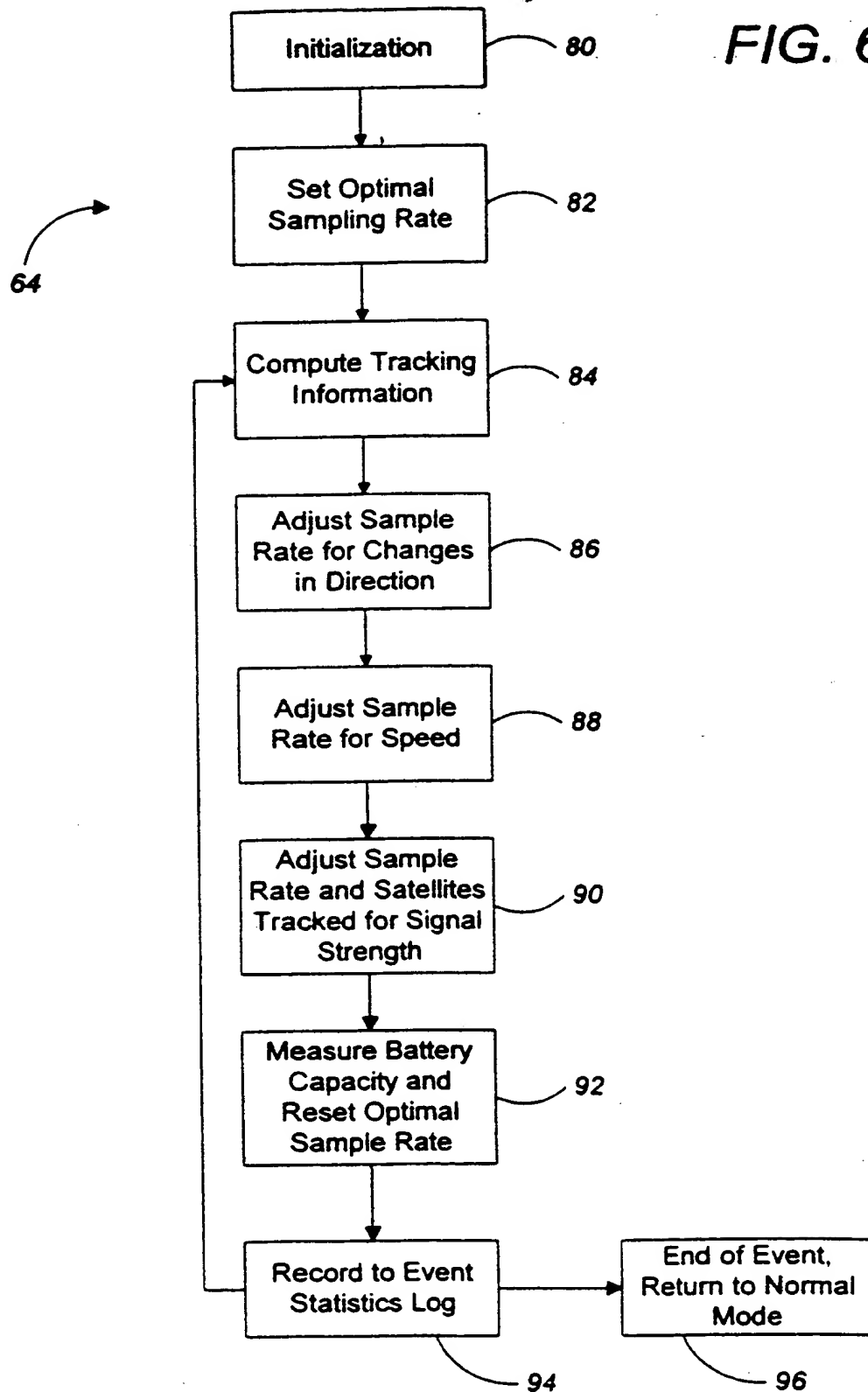
| 72<br>time | 74<br>distance | 76<br>speed | 78<br>heart rate |
|------------|----------------|-------------|------------------|
| 0:01:00    | 0.2 miles      |             |                  |
| 0:02:30    | 0.5 miles      |             |                  |
| 0:03:30    | 0.6 miles      |             |                  |
| 0:05:00    | 0.9 miles      |             |                  |
| ⋮          | ⋮              | ⋮           | ⋮                |
|            |                |             |                  |

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FIG. 5

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FIG. 6



# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/12229

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 G01S11/02 G01C21/16

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G01S G01C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No. |
|------------|---|-----------------------|
| X          | WO 97 24577 A (ROCKWELL INTERNATIONAL CORP<br>;CROYLE STEVEN R (US); SPENCER LARRY E)<br>10 July 1997 (1997-07-10)              | 1,4-6                 |
| Y          | page 3, line 1 - line 4<br>page 6, line 1 - line 10<br>page 7, line 18 - line 19<br>page 8, line 3 - line 13<br>page 8, line 21 | 2,3                   |
| Y          | ---<br>US 5 627 548 A (WOO ARTHUR N ET AL)<br>6 May 1997 (1997-05-06)<br>column 1, line 34 - line 50                            | 2,3                   |
| A          | ---<br>DE 196 09 345 A (HUBER FRANZ FERDINAND)<br>16 October 1997 (1997-10-16)<br>the whole document<br>-----                   | 1-6                   |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*Z\* document member of the same patent family

Date of the actual completion of the international search

17 September 1999

Date of mailing of the international search report

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# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US 99/12229

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-6

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.



FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1. Claims: 1-6

Travel distance tracking device integrated into a wristwear device

2. Claims: 7-20

GPS tracking device with improved accuracy

3. Claims: 21-28

Power management for a GPS tracking device

4. Claims: 29-31

Viewing of wristwear device during times of darkness

5. Claims: 32-36

User interface for operating wristwear device

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 99/12229

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)   | Publication<br>date      |
|---|---------------------|------------------------------|--------------------------|
| WO 9724577 A                              | 10-07-1997          | US 5862511 A<br>EP 0870173 A | 19-01-1999<br>14-10-1998 |
| US 5627548 A                              | 06-05-1997          | US 5781155 A                 | 14-07-1998               |
| DE 19609345 A                             | 16-10-1997          | NONE                         |                          |